

Coastal Hydrology for the Trinity-San Jacinto Estuary

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Bays & Estuaries Program
Surface Water Resources Division
Texas Water Development Board
1700 N. Congress Avenue
Austin, Texas 78711

Technical Authors

Caimee Schoenbaechler, M.E.M.
Carla G. Guthrie, Ph.D.

Technical Contributor

Qingguang Lu, P.E.

Purpose

This technical memo documents the procedure for estimating combined freshwater inflow data and freshwater inflow balance for the Trinity-San Jacinto Estuary and the specifics related to producing TWDB hydrology dataset version #TWDB201101 for this estuary.

Introduction

The goal of the Texas Water Development Board (TWDB) Coastal Hydrology program is to provide estimates of historical freshwater inflows into Texas bays and estuaries to support environmental and water planning studies. The earliest freshwater inflow estimates were compiled in a series of reports published by the Texas Department of Water Resources between 1980 and 1983. Monthly inflows to the seven major estuaries in Texas for the period 1941 - 1976 were estimated in those studies, with estimates for the Trinity-San Jacinto Estuary published in Chapter 4 of LP-113, *Trinity-San Jacinto Estuary: A Study of the Influence of Freshwater Inflows* (TDWR 1981, available on the TWDB website or upon request).

Inflow records for each estuary have been updated periodically since then in support of ongoing research and planning studies both within and external to TWDB. Additionally, subsequent updates are provided in daily as well as monthly formats. This report covers the most recent update of freshwater inflow estimates for the Trinity-San Jacinto Estuary which extends the dataset through 2010. Therefore, complete hydrology is available for this estuary for 1941 - 2010, with daily estimates of inflows available only after 1977.

Estimates of Surface Inflows

Detailed studies of hydrology of the areas draining to the Trinity-San Jacinto Estuary include gaged watersheds and ungaged portions of the Trinity and San Jacinto River basins, as well as other small coastal basins. The combination of Gaged Inflows + Ungaged Inflows (Modeled Runoff) + Return Flows – Diversions, where the ungaged inflows, return flows, and diversions are below the lowest gaging station, provide for estimates of **Surface Inflow** (also referred to as *combined freshwater inflow*) to the estuary. The **Freshwater Inflow Balance** consists of Surface Inflows + Precipitation on the estuary – Evaporation from the estuary. Although inflow estimates are updated on an ongoing basis, there are two distinct periods of estimation. Before 1977, inflow estimates are available only in monthly intervals. Starting in 1977 and thereafter, inflow estimates became available on a daily basis.

1941 - 1976 Period of Record

This dataset used measurements from U.S. Geological Survey (USGS) stream gages and one reservoir elevation gage (Lake Houston) to determine flows in gaged watersheds and rainfall-runoff estimates from a water yield model to determine flows from ungaged watersheds (TDWR 1981). In most estimates of coastal hydrology, flows in ungaged areas were adjusted for known agricultural, municipal, and industrial return flows obtained from the Texas Department of Water Resources (TDWR 1981). Municipal and industrial return flows within the ungaged watersheds were estimated from data provided by the TDWR self-reporting system, while irrigation return flows in ungaged watersheds were calculated using agency data collected in rice irrigation return flow studies (TDWR 1981). Reported diversions for municipal, industrial, and irrigation use within ungaged watersheds were provided by the TDWR reported water usage system. Data on inflows to the Trinity-San Jacinto Estuary for 1941 - 1976 are available as monthly or annual estimates.

1977 - 2010 Period of Record

This dataset used measurements from USGS stream gages and one reservoir elevation gage (Lake Houston) to determine flows in gaged watersheds. For ungaged watersheds, rainfall-runoff estimates from the Texas Rainfall-Runoff (TxRR) model were adjusted for known diversion and return flows, obtained from the Texas Commission for Environmental Quality (TCEQ) and TWDB Irrigation Water Use estimates. In some cases, diversion and return flow data may be obtained through other entities, such as in the TWDB report, *Coastal Hydrology for the Guadalupe Estuary: Updated Hydrology with Emphasis on Diversion and Return Flow Data for 2000 – 2009* (Guthrie and Lu 2010), where recent diversion and return flow data was obtained from HDR, Inc. Data on inflows to the Trinity-San Jacinto Estuary for 1977 - 2010 are available as daily, monthly, or annual estimates.

Gaged Watersheds

Daily flow recorded at twelve USGS stream gages and from one reservoir elevation gage was used to develop the gaged inflow component of surface inflows to the Trinity-San Jacinto Estuary. Approved USGS stream flow data was obtained through December 2010, but was provisional for October through December 2010. Table 1 lists the USGS stream gages and corresponding period of record utilized in estimating combined freshwater inflows to the bay system.

Table 1. USGS stream gage number, location, and period of record used to develop the gaged inflow component of surface inflows to the Trinity-San Jacinto Estuary. Gaged flows were modeled using TxRR where gaged data was missing, as shown by the modeled period.

Estuary	USGS Gage Station Number	USGS Gage Location	Utilized Period of Record	Modeled Period
Trinity-San Jacinto	8067500	Cedar Bayou near Crosby	1971 - 1999 and 2001 - 2010	10/1/1999 - 9/30/2001
	8075000	Brays Bayou at Houston	1941 - 2010	none
	8075500	Sims Bayou at Houston	1952 - 1995	After 9/30/1995
	8076000	Greens Bayou near Houston	1952 - 2010	none
	8076500	Halls Bayou at Houston	1952 - 1993 and 2000 - 2010	10/1/1993 - 9/30/2000
	8075770	Hunting Bayou at IH 610	1964 - 2010	none
	8075730	Vince Bayou at Pasadena	1971 - 2010	none
	8074500	Whiteoak Bayou at Houston	1941 - 2010	none
	8073600	Buffalo Bayou at West Belt Drive	1971 - 2010	none
	8077000	Clear Creek near Pearland	1947 - 1994	After 9/4/1994
	8078000	Chocolate Bayou near Alvin	1959 - 2010	none
	8066500	Trinity River at Romayor	1941 - 2010	none
	8072000	Lake Houston (reservoir elevation gage)	1954 - 2010	none

Ungaged Watersheds

The number of ungaged watersheds for which ungaged inflows are estimated has changed through time as USGS gages were installed or removed. Initial estimates from 1941 – 1976 were determined using 18 ungaged watersheds. Subsequent estimates from 1977 – 2010 were determined based on 23 ungaged watersheds, although one watershed (#08020) was not used in the calculation of inflows from 1987 – 2005 due to a lack of available data. The increase in the number of watersheds over the period of record is due to a subdivision of larger watersheds into smaller ones, as well as the addition of new watersheds. Additionally, watersheds were re-numbered various times throughout the period of record. Figures 1 - 2 show the delineation of watershed boundaries and their changes from 1941 - 2010.

The modeled runoff component of surface inflows is estimated using a rainfall-runoff model. Before 1977, stream flows in ungaged watersheds were obtained using a *water yield model* which required daily precipitation, Soil Conservation Service average curve numbers, and soil depletion index (TDWR 1981). This water yield model provided for monthly estimates of ungaged inflows – not daily. TWDB does not have daily estimates of ungaged inflows for the period prior to 1977.

Since 1977, however, TWDB has used the Texas Rainfall-Runoff (TxRR) model to estimate daily stream flows in ungaged watersheds. This model is conceptually similar to the Agricultural Research Service

(ARS) rainfall-runoff model which is based on the Soil Conservation Service's curve number method to estimate direct runoff from a precipitation event. TxRR, however, has four key differences: (1) Use of simpler and more straightforward mathematics, (2) Introduction of 12 monthly depletion factors, instead of the single depletion factor used in the ARS Model, (3) Introduction of a base flow component into the model, and (4) calculation of daily runoff. TxRR has been used to estimate daily stream flows from over 50 coastal ungaged watersheds as a part of the TWDB Bays & Estuaries Coastal Hydrology Program to study freshwater inflows to Texas bays and estuaries.

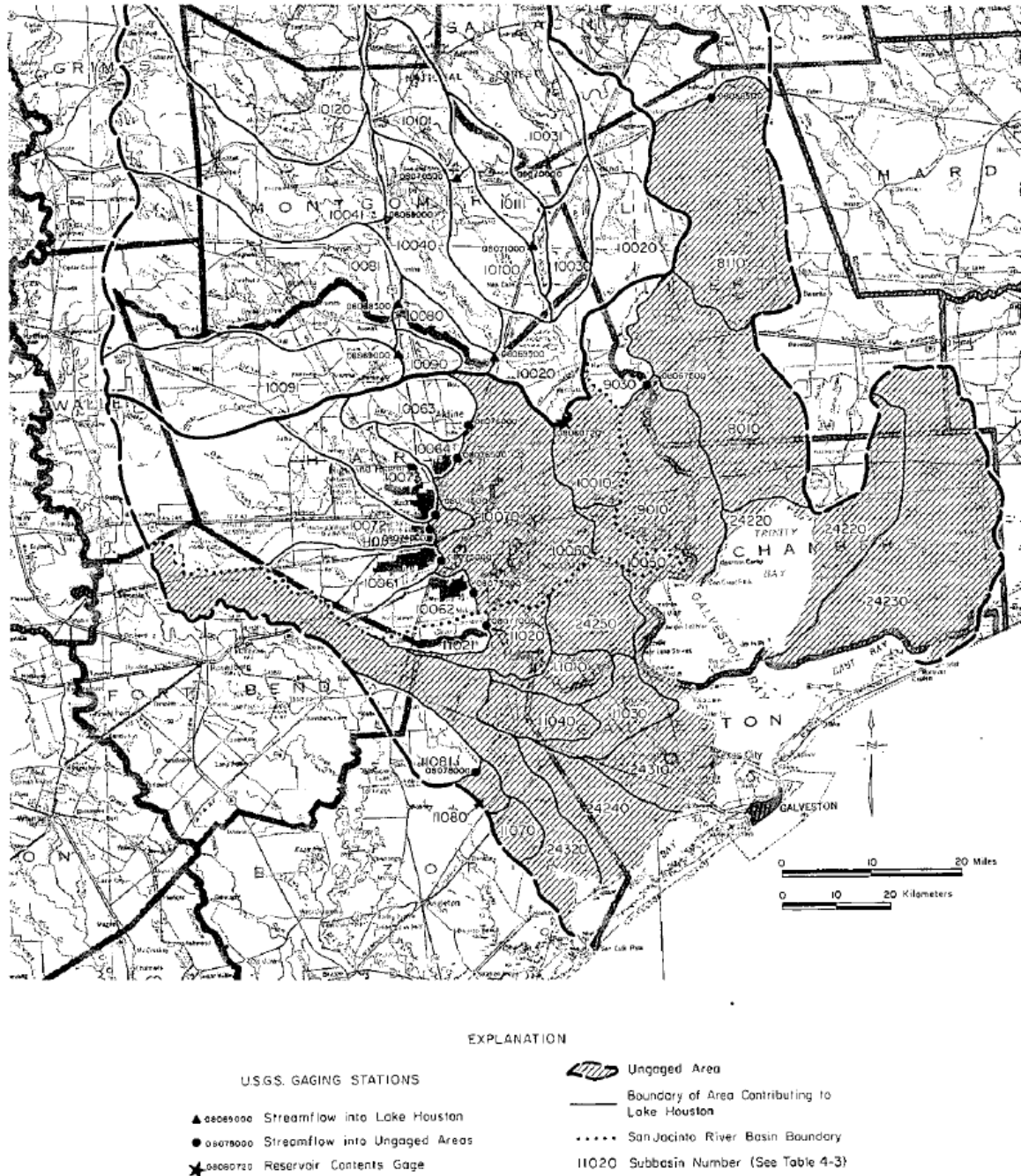


Figure 1. Ungaged watershed delineation used to determine ungaged inflows to the Trinity-San Jacinto Estuary from 1941 - 1976. Ungaged watersheds are shown with hatch marks.

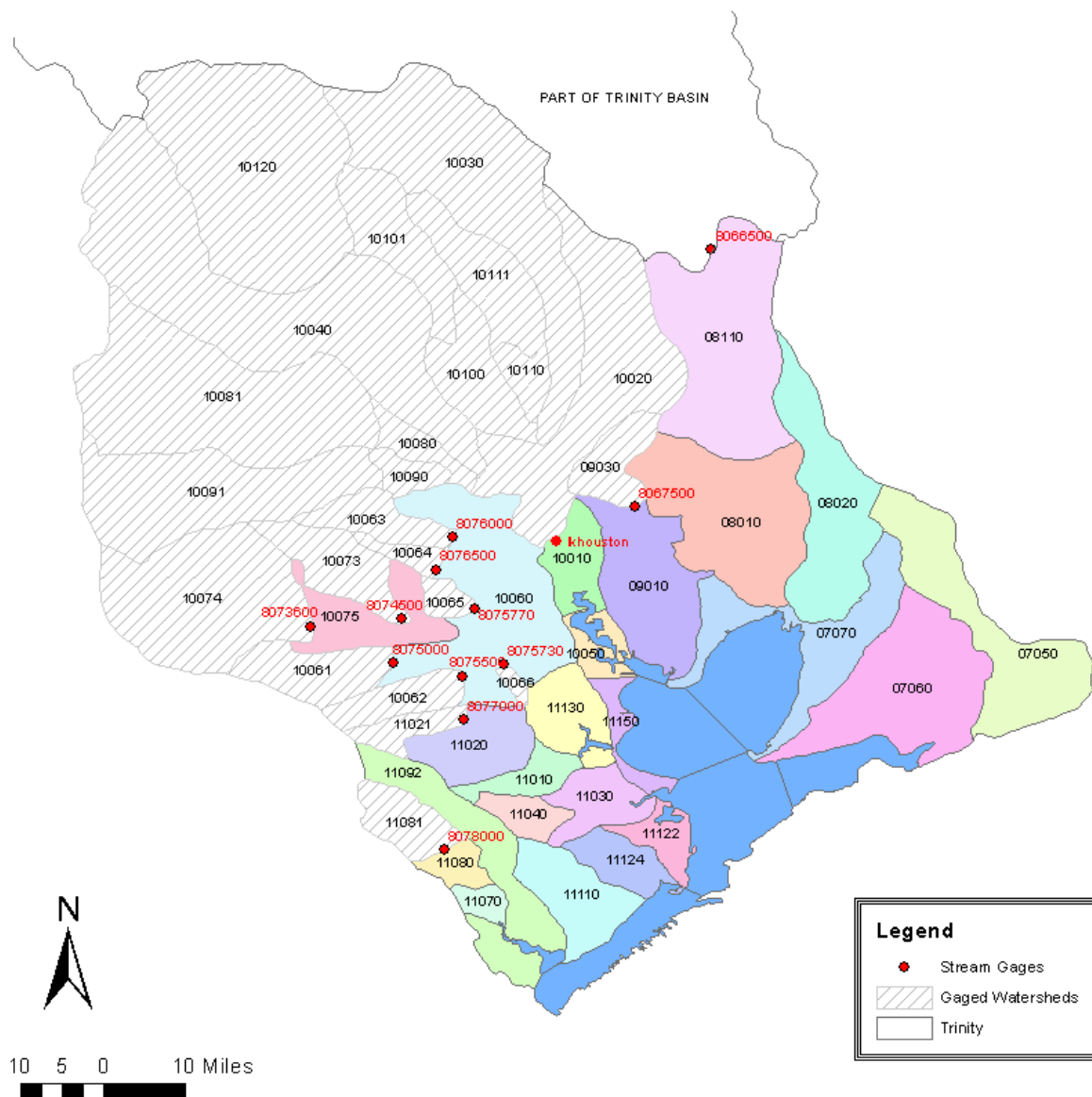


Figure 2. Ungaged watershed delineation used to determine ungaged inflows to the Trinity-San Jacinto Estuary from 1977 - 2010. Gaged watersheds are represented with hatch marks, with associated stream gage locations designated by red circles. Watershed #08020 was not used in the calculation of coastal hydrology estimates from 1987 – 2005 due to a lack of available data.

Diversions and Return Points

Diversions and return flows within the ungaged watersheds are accounted for when estimating total freshwater inflow to the estuary. The major water rights and major discharge permits in the Trinity River and San Jacinto River basins and surrounding coastal basins of the Trinity-San Jacinto Estuary are listed in Appendix A, with locations of these permits shown in Figure 3.

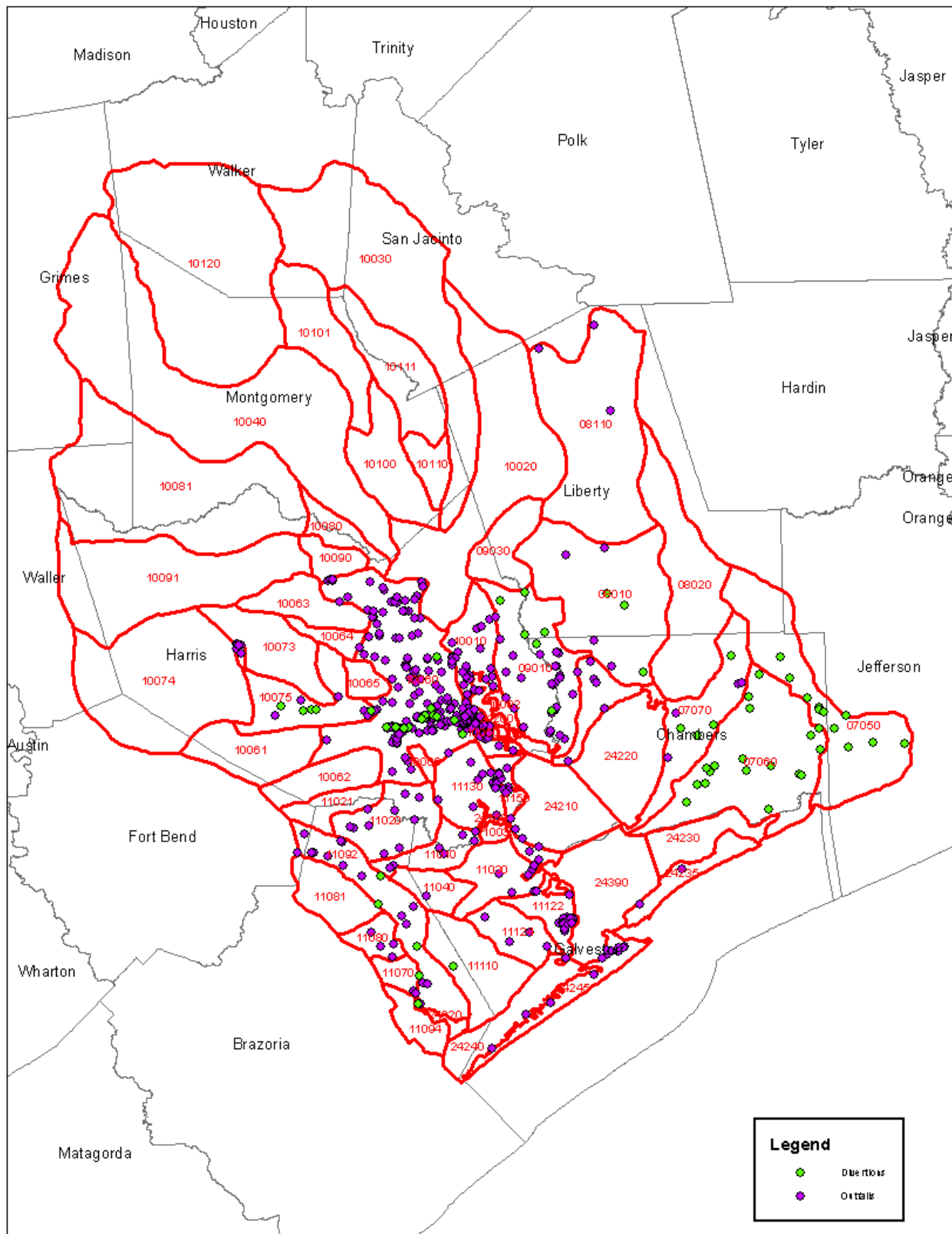


Figure 3. Location of permitted diversion points (green circles) and wastewater outfalls (purple circles) in the Trinity River and San Jacinto River basins and surrounding coastal basins.

Estimates of Freshwater Inflow Balance

Freshwater Inflow Balance to the estuary includes estimates of **Surface Inflow** to the estuary + **Precipitation** on the Estuary – **Evaporation** from the Estuary. Due to limitations on the unaged inflows prior to 1977 and on estimates of evaporation throughout the period of record, estimates of the freshwater inflow balance are available only in monthly intervals. However, daily estimates can be obtained by evenly dividing a monthly estimate by the number of days in the month.

The bay surface area which was used to calculate precipitation onto and evaporation from the estuary has changed over time. Prior to 1977, the total bay surface area was estimated to be 552.7 square miles (TDWR 1981); whereas, after 1977, the total bay surface area was estimated to be 541.5 square miles. The 11.2 square mile difference (approximately 2%) between the two estimation periods does not greatly affect the precipitation or evaporation estimates.

Precipitation

Direct precipitation onto the surface of the Trinity-San Jacinto Estuary was calculated using Thiessen-weighted precipitation techniques as described in LP-113 (TDWR 1981). Station based rainfall data was obtained from the National Weather Service (NWS) and processed using Arc/Info Macro Language. Bay segments (#24210, #24220, #24230, #24240, #24250, #24390, and #24320) were used to calculate precipitation on the bay by summing the area-weighted rainfall of the Thiessen polygon fragments within the bay watershed. Figure 4 shows the Thiessen polygons that were drawn to be coincident with rainfall stations to calculate watershed rainfall. Annual estimates of precipitation onto the surface of the bay, as prepared for hydrology version #TWDB201101 for the Trinity-San Jacinto Estuary are shown in Figure 5.



Figure 4. Rainfall stations (◆) and Thiessen polygons (red lines) used to estimate direct precipitation onto the Trinity-San Jacinto Estuary.

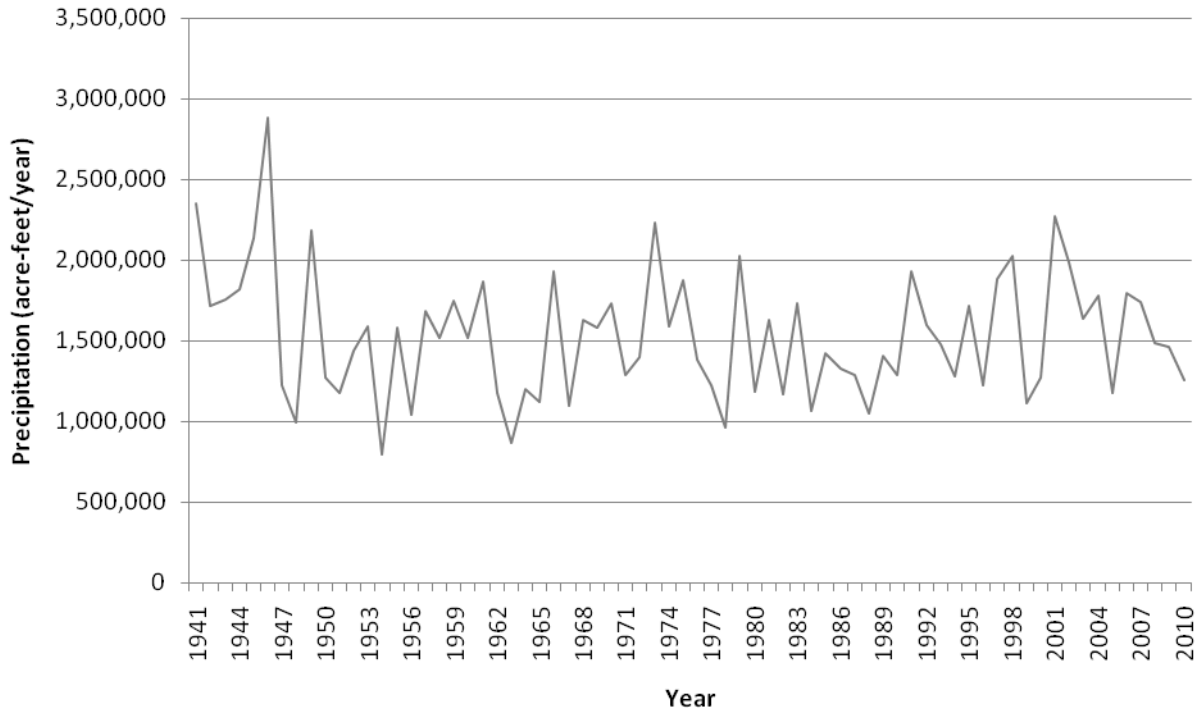


Figure 5. Annual estimates of precipitation (in acre-feet/year) for the Trinity-San Jacinto Estuary for 1941 - 2010.

Evaporation

Evaporation was calculated for the surface area of the estuary using TWDB and NWS pan evaporation data to estimate evaporation rates. Bay watersheds used to calculate evaporation include watersheds #24210, #24220, #24230, #24240, #24250, #24390, and #24320, which are all located within quadrangles 812 and 813 (Figure 6). Total water evaporated from these areas was calculated by multiplying the watershed area by the evaporation rates obtained from TWDB. Evaporation rates were determined with a GIS-based program, *ThEvap*, using TWDB and NWS pan evaporation data. The *ThEvap* program replaced an older program, *WD0300*, previously run by the Texas Department of Water Resources (<http://midgewater.twdb.state.tx.us/Evaporation/evap.html>). Estimates of average annual evaporation from the surface of the estuary, as prepared for hydrology version #TWDB201101 for the Trinity-San Jacinto Estuary, are shown in Figure 7.

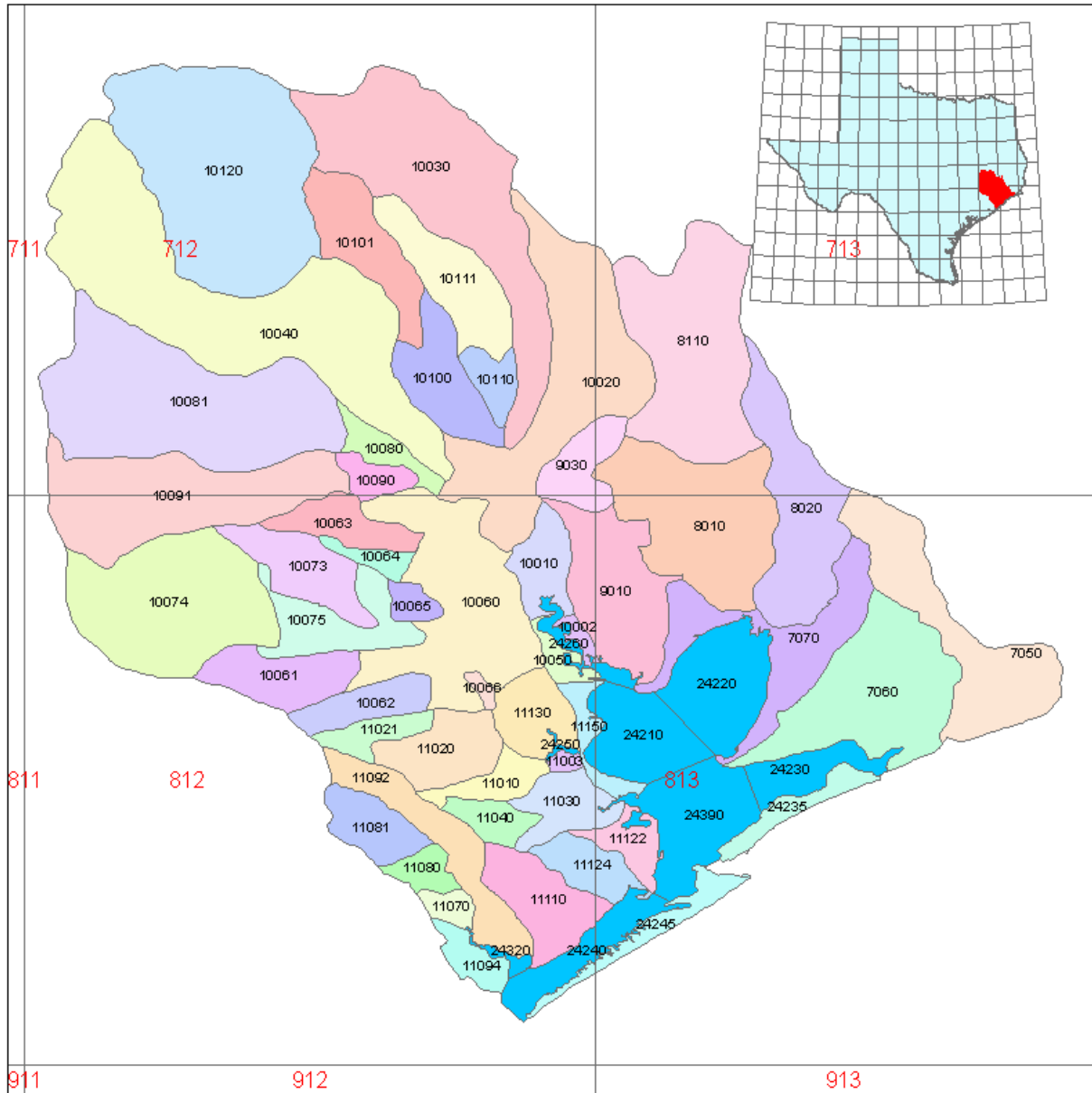


Figure 6. TWDB evaporation quadrangles used to estimate evaporation. Quadrangles 812 and 813 are used to estimate evaporation from the Trinity-San Jacinto Estuary bay segments #24210, #24220, #24230, #24240, #24250, #24390, and #24320. Please note that historically watershed #24260 was not included in the calculation.

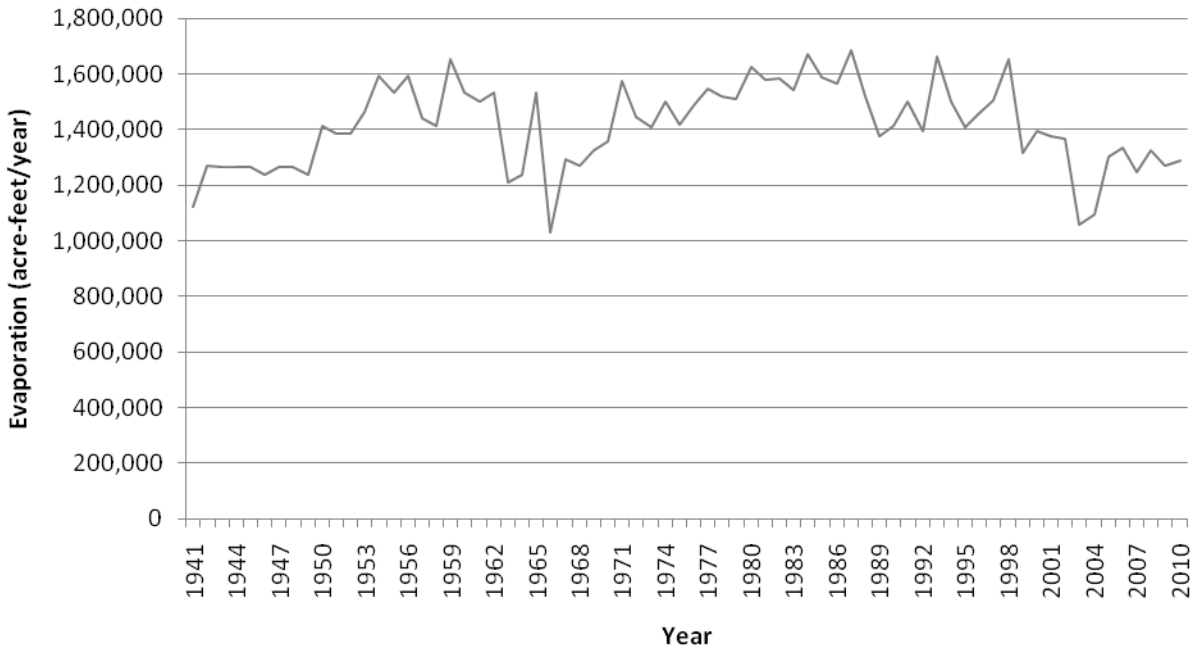


Figure 7. Annual estimates of evaporation (in acre-feet/year) for the Trinity-San Jacinto Estuary for 1941 - 2010.

Hydrology: Version #TWDB201001

TWDB coastal hydrology version #TWDB201001 for the Trinity-San Jacinto Estuary included gaged and ungaged inflows through December 2008, with all estimates prior to 1977 coming from those reported in LP-113 (TDWR 1981). Diversion data for municipal, industrial, and irrigation use within the ungaged watersheds were provided by the Texas Department of Water Resources (TDWR) reported water usage system. Return flows from municipalities and industries within the ungaged watersheds were estimated from data provided by the TDWR self-reporting system. Irrigation return flows were calculated using agency data collected in rice irrigation return flow studies. After 1976, raw diversion data was obtained from TCEQ for the period from 1977 - 2005. Industrial and municipal return flow data also was obtained from TCEQ for the period from 1977 - 2007. Additional return flow data was obtained from TWDB's agricultural return flow estimates through December 2005. Note that while this version of hydrology extends estimates of freshwater inflow from 1941 through 2008, not all components were updated through 2008. Specifically, diversion and return flow estimates are not considered complete for the 2005 - 2008 period. Additionally, diversions appear to decrease substantially after 2000. Understanding the cause of this decrease will require additional investigation. Note that the same decrease is apparent in the two subsequent hydrology versions (#TWDB201004 and #TWDB201101) described in this document.

Hydrology version #TWDB201002 and version #TWDB201003 were not created for the Trinity-San Jacinto Estuary.

Hydrology: Version #TWDB201004

TWDB coastal hydrology version #TWDB201004 for the Trinity-San Jacinto Estuary extended gaged inflow data through November 2009 and used provisional data for December 2009. Ungaged inflows were updated from coastal hydrology version #TWDB201001 using approved daily precipitation data from the NWS through November 2009, with provisional data for December 2009. Diversions from TCEQ were the same as in version #TWDB201001, but additional data extended the dataset through 2009. Return flows were the same as in version #TWDB201001, but additional data obtained from TCEQ extended the data through December 2009, and agricultural return flow data obtained from TWDB were extended to December 2007. Note that while this version of hydrology extends estimates of freshwater inflow from 1941 through 2009, not all components were updated through 2009. Gaged inflows and precipitation data were provisional for December 2009, and agricultural return flows were not available after 2007, and thus were not included in the estimates after 2007.

Hydrology: Version #TWDB201101

This version of coastal hydrology for the Trinity-San Jacinto Estuary represents the most up-to-date dataset for this estuary. The dataset was updated from version #TWDB201004 and extended gaged, ungaged, precipitation, and evaporation estimates through 2010. However, diversion and return flow data was not available for 2010 and so were not included in the estimates. As with version #TWDB201004, agricultural return flows were considered complete only through 2007 and were not updated thereafter. Gaged flow data was provisional from October through December 2010, as well as precipitation data from September through December 2010. Figure 8 displays the combined annual surface inflow to the Trinity-San Jacinto Estuary as calculated for version #TWDB201101 for the period from 1941 – 2010.

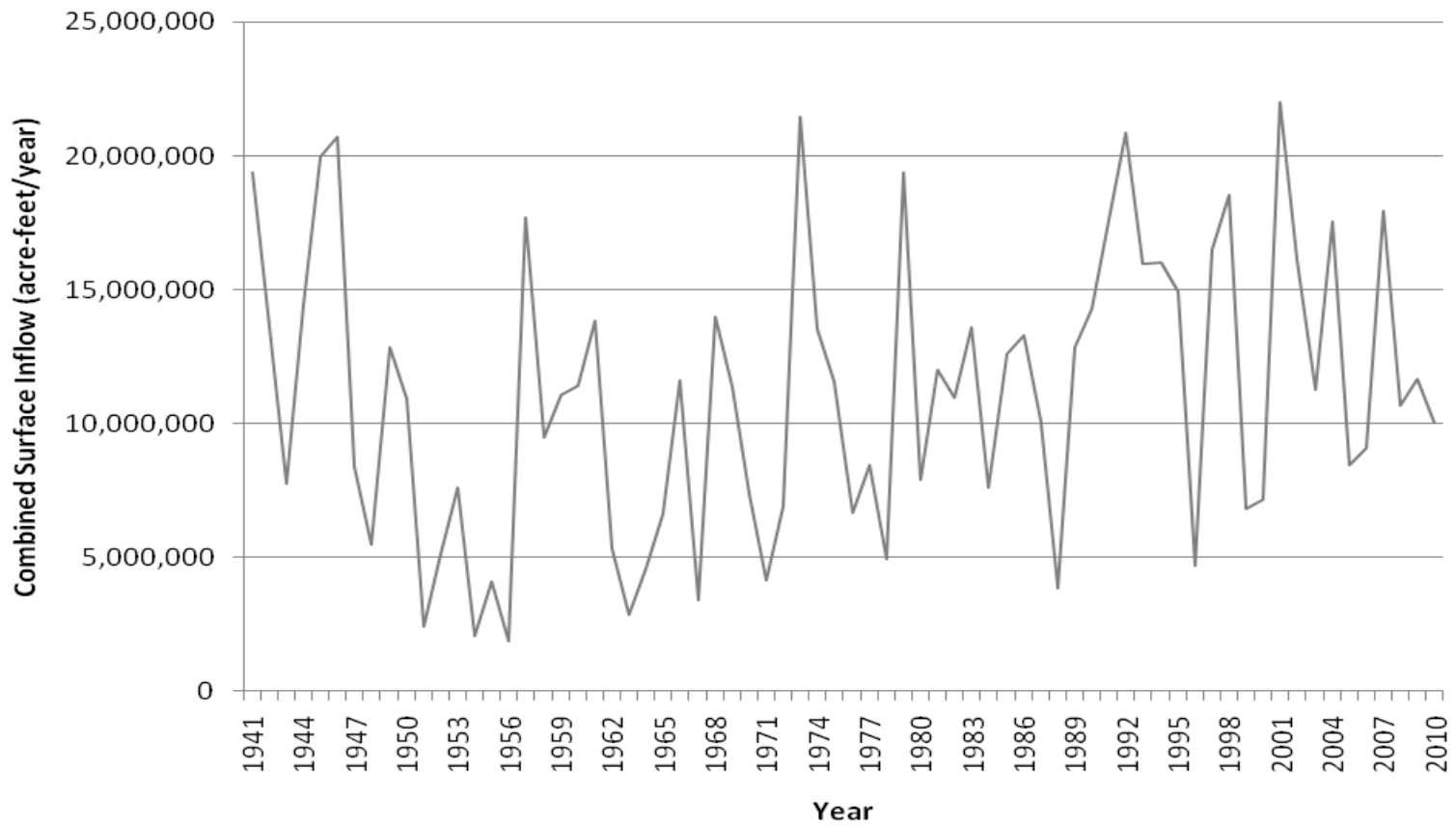


Figure 8. Annual estimates of combined freshwater inflow to the Trinity-San Jacinto Estuary as calculated by version #TWDB201101 for the period from 1941 – 2010. *Note:* diversions and returns were not updated for 2010.

Discussion

Version #TWDB201101 of coastal hydrology for the Trinity-San Jacinto Estuary, presented herein, is the most up-to-date data set representing not only combined freshwater inflows but also the individual components of inflows (*i.e.*, gaged flows, ungaged flows, diversions, return flows) for this estuary for the 1941 – 2010 period. Appendix B summarizes recent updates, by version, to the estimates of hydrology for the Trinity-San Jacinto Estuary. Appendix C lists annual combined inflow along with the four components, as well as estimates for evaporation and precipitation on the estuary and the total freshwater inflow balance of the Trinity-San Jacinto Estuary. Appendix D lists summary statistics for the inflow components over the 1941 - 2010 period.

During the period from 1941 - 2010, gaged inflow from the Trinity and San Jacinto Rivers accounted for 71 percent of combined inflow, while ungaged flows accounted for 27 percent of combined inflow. In the Trinity and San Jacinto River basins, average diversions totaled two percent of combined freshwater inflows, and average return flows totaled four percent of inflows. Average combined surface inflow to the Trinity-San Jacinto Estuary over the study period was approximately 11.1 million acre-feet per year, and ranged from a minimum of 1.8 million acre-feet in 1956 to a maximum of 22 million acre-feet in 2001.

Finally, when considering total freshwater inflow balance, evaporation from and precipitation onto the surface of the estuary also must be considered. During the 1941 through 2010 period, the freshwater inflow balance varied from a minimum of 1.3 million acre-feet in 1954 to a maximum of 22.9 million acre-feet in 2001, and averaged 11.2 million acre feet per year. Due to high precipitation and inflows relative to evaporation, the Trinity-San Jacinto Estuary has not experienced a negative freshwater inflow balance during the period of record.

Literature Cited

- TDWR. 1981. *Trinity-San Jacinto Estuary: A Study of the Influence of Freshwater Inflows*. LP-113. Texas Department of Water Resources, Austin, Texas.
- Guthrie, C.G. and Q. Lu. 2010. *Coastal Hydrology for the Guadalupe Estuary: Updated Hydrology with Emphasis on Diversion and Return Flow Data for 2000-2009*. Texas Water Development Board, Austin, Texas.

Appendix A. Major water rights and discharge permits in the Trinity-San Jacinto basin below the lowest USGS stream gages.

	Water Right Number	Owner
	DIVERSION	3920
3921		Richard L Shuman
3922		Cedar Bayou LTD
3923		Billy E Murff
3924		FVL LTD
3925		FPL Farming LTD
3926		NRG Texas Power LLC
3944		W J Winzer Jr Et Al
3945		W J Winzer Jr
3951		Don Wesley Lagow Et Al
3952		Solmon Wesley Barrow Et Al
3953		Wayne Morris Et UX
3954		Louise Barrow Gorton
3985		River Oaks Country Club
3986		Museum Of Fine Arts
3987		Gulf Coast Portland Cement Co
3988		AES Western Power LLC
3989		Agrifos Fertilizer Inc
3990		Greensport/Ship Channel Partners LP
3991		Chevron Phillips Chemicals Company LP
3992		Ethyl Corporation
3993		Oiltanking Houston LP
3995		Texas Parks & Wildlife Dept
4045		United States Dept Of Energy
4228		Nolia F Boudreaux Et Al
4229		Patrick & Michael Phelan
4248		Trinity River Authority
4277		American Rice Growers Coop
4287		W E Jenkins Jr Et Al
4288		Gene A Nelson Et Al
4289	Octavia F Stanley	
4290	Thomas Lloyd Fahring Jr Family Trusts	
4291	John G Middleton Et Al	
4292	Donald G Nelson Et Al	
4293	Edmonds Brothers Farms	
4294	Brown Foundation Inc	

DIVERSION	4295	Jewel Fitzgerald
	4296	U S Anahuac Wildlife Refuge
	4297	Chambers, County Of
	4298	Brown Brothers Farm
	4299	Ocie R Jackson
	4300	Bobby Jack Enloe Et Ux
	4301	Barrow Ranches
	4302	United States Dept Of Interior
	4303	Mr. and Mrs. Don W Lagow
	4304	Charles T Jones Et Al
	4305	William S Edwards
	4306	W S Edwards Family LP
	4307	Trinity Bay Conservation Dist
	4308	Jerry Devillier Et Al
	4309	Spindletop Bayou Farms
	4310	W J Winzer Jr
	4311	John Middleton
	4312	Jess Matthews Jr Et Al
	4313	Deaton-Pipkin Partnership
	4314	Max L Fortenberry Et Al
	5016	John M Blackwell
	5059	Jere Ruff
	5271	Devers Canal Rice Pro Assn Inc
	5321	Solutia Inc
	5336	Houston Country Club
	5353	Vopak Terminal Galena Park Inc
	5356	John Russell Isaacs Co-Trustee Et Al
	5357	Gulf Coast Water Authority
	5358	Ineos USA LLC
	5359	Alvin Golf & Country Club
	5360	James Scopel
	5362	Harris Co Flood Control Dist
5430	Valero Refining Texas LP	
5467	Randy G Price Et Ux	
5507	Arkema Inc	
5522	Deer Park, City Of	
5716	Magellan Terminals Holdings LP	
5762	Memorial Park Golf Course	

	NPDES Number*	Owner
RETURNS	TX0002836	Millenium Petrochemicals Corp
	TX0002933	Dow Chemical Co The
	TX0002976	Valero Refining - Texas LP
	TX0003239	Praxair Inc
	TX0003247	Lyondell Citgo Refining LP
	TX0003522	Bp Products North America Inc
	TX0003531	Equistar Chemicals LP
	TX0003689	The Goodyear Tire & Rubber Co
	TX0003697	Marathon Petroleum Co LLC
	TX0003832	Degussa Engineered Carbons LP
	TX0003867	Gulf Sulphur Services Ltd LP
	TX0003875	Solutia Inc & Equistar Chemicals LP
	TX0003948	Chevron Phillips Chemical Company LP
	TX0004022	Petroleum Coke Grinding Inc
	TX0004731	Albemarle Corp
	TX0004766	Bp Amoco Chemical Co
	TX0004821	Ineos USA LLC
	TX0004863	Shell Oil Co
	TX0004871	Shell Oil Co & Deer Park Refining LP
	TX0004944	Air Products LLC
	TX0004961	Texas Petrochemicals And Kemiron Gulf Inc
	TX0005380	Gulf Coast Waste Disposal Authority
	TX0005479	Martin Product Sales LLC
	TX0005576	Reichhold Inc
	TX0005754	Port Of Galveston And Gulf Copper And Manufacturing Corp
	TX0005860	Texmark Chemicals Inc
	TX0005941	Clean Harbors Deer Park LP
	TX0006009	Valero Refining - Texas LP
	TX0006033	Ineos Polyethylene North America
	TX0006068	Exxonmobil Oil Corp
	TX0006084	Rohm And Haas Texas Inc
	TX0006157	Gulbrandsen Technologies Inc
	TX0006173	Rhinopak LP
	TX0006254	Reedhycalog LP
	TX0006335	Oxy Vinyls LP
	TX0006378	NRG Texas Power LLC
TX0006386	NRG Texas LP	
TX0006386	NRG Texas Power LLC	
TX0006416	NRG Texas Power LLC	

RETURNS	TX0006459	NRG Texas Power LLC
	TX0006688	Akzo Nobel Chemicals Inc & Akzo Nobel Polymer Chemicals LLC
	TX0007048	The Lubrizol Corp
	TX0007056	United States Gypsum Co
	TX0007064	Arkema Inc
	TX0007145	Magellan Terminals Holdings LP
	TX0007285	Agrifos Fertilizer Inc
	TX0007323	ISP Technologies Inc
	TX0007412	Oxy Vinyls LP
	TX0007421	Total Petrochemicals USA Inc
	TX0007439	GB Biosciences Corp
	TX0007552	Chevron Phillips Chemical Co LP
	TX0007706	US Denro Steels Inc
	TX0008001	Greif Industrial Packaging & Services LLC
	TX0008150	Oxy Vinyls LP
	TX0008184	Ohmstede Inc
	TX0008524	Greensport/Ship Channel Partners LP
	TX0008851	Texas Medical Center Central Heating & Cooling Services Corp
	TX0020061	City Of Jamaica Beach
	TX0020079	Galveston County FWSD 6
	TX0020109	City Of Baytown
	TX0020117	City Of Baytown
	TX0020311	Galveston County MUD 12
	TX0020320	Humble Partners LP
	TX0020800	Greenwood Utility District
	TX0020991	Sheldon Road MUD
	TX0021369	Bacliff MUD
	TX0021822	Bayview MUD
	TX0022250	City Of Seabrook
	TX0022462	Harris County FWSD No 47
	TX0022543	Clear Lake City Water Authority
	TX0022756	Harris County WCID 21
	TX0022799	City Of La Porte
	TX0023230	Newport MUD
	TX0023311	Harris County WCID 1
	TX0023337	Oak Manor MUD
TX0023655	Galveston County WCID 1	
TX0023671	Galveston County WCID 8	
TX0023833	City Of Nassau Bay	
TX0023949	City Of Texas City	

RETURNS	TX0024554	City Of Alvin
	TX0024589	City Of Webster
	TX0025062	Harris County FWSD 51
	TX0025291	City Of Houston
	TX0025321	City Of Deer Park
	TX0025623	El Dorado Utility District
	TX0027111	Harris County FWSD 6
	TX0027146	Harris County WCID 50
	TX0027332	A K Interests-Hunterwood LP
	TX0027791	City Of Galveston
	TX0030228	Lyondell Chemical Co
	TX0030571	Dallas Chemical Technologies Inc
	TX0030929	Vopac Terminal Galena Park Inc
	TX0030937	Vopak Logistics Services Usa Inc
	TX0031429	Centerpoint Energy Houston Electric LLC
	TX0031461	Douglas Utility Co
	TX0031534	Hfotco LLC
	TX0032085	Champs Water Co
	TX0032735	City Of Pearland
	TX0032743	City Of Pearland
	TX0033944	City Of Anahuac & Trinity Bay Conserv Dist
	TX0034401	City Of Humble
	TX0034428	Harris County WCID 84
	TX0034886	City Of Houston
	TX0034916	City Of Houston
	TX0035009	City Of Houston
	TX0035106	City Of Houston
	TX0042081	Gulf Utility Service Inc
	TX0047309	City Of Galveston
	TX0047457	Memorial Villages Water Authority
	TX0047881	City Of Pasadena
	TX0052591	Gulf Coast Waste Disposal Authority
	TX0053023	Caltex Holdings LP
	TX0053317	City Of Mont Belvieu
TX0053970	City Of Jacinto City	
TX0054151	Crosby MUD	
TX0054917	Trinity Bay Conservation District	
TX0056057	City Of Hillcrest Village	
TX0057053	Harris County MUD No 50	
TX0057185	City Of Galena Park	

RETURNS	TX0057258	Martin Operating Partnership LP
	TX0057304	City Of South Houston
	TX0057843	Gulf Coast Waste Disposal Authority
	TX0058963	Harris County MUD 109
	TX0062243	City Of Hitchcock
	TX0062952	Royalwood MUD
	TX0063037	City Of Houston
	TX0063045	City Of Houston
	TX0063053	City Of Houston
	TX0063070	City Of Houston
	TX0063231	Texas A&M University At Galveston
	TX0065943	S I Enterprises LLC
	TX0065986	Rescar Industries Inc
	TX0066125	City Of Galveston
	TX0066656	Gray Sr, Walter Madison
	TX0067539	BCWK LP
	TX0068349	Intercontinental Terminals Co Llc
	TX0068438	Cedar Bayou Park Ud
	TX0068683	Aqua Utilities Inc
	TX0068926	J&S Water Co LLC
	TX0069493	Lyondell Chemical Co
	TX0069728	Gulf Coast WDA & City Of Friendswood
	TX0069736	City Of Houston
	TX0070165	Sheldon Road MUD
	TX0070416	Oxy Vinyls LP
	TX0070645	Port Terminal Railroad Assn
	TX0070955	SWS Holdings - Brady Island LP
	TX0071447	City Of League City
	TX0071897	Harris County MUD 148
	TX0071978	San Leon MUD
	TX0072168	Keeshan & Bost Chemical Co Inc
	TX0072320	Georgia Gulf Chemicals & Vinyls LLC
	TX0072524	Dynamic Products Inc
	TX0074021	Trail Of The Lakes MUD
	TX0074268	Harris County MUD 49
	TX0074276	Sunoco Inc (R & M)
TX0074284	City Of Liberty	
TX0074446	Harris County MUD 49	
TX0075060	Oxid LP	
TX0075078	G & C Investment Co LLC & Garlock Sealing	

RETURNS	TX0075302	LBC Houston LP
	TX0075311	Stan Trans Partners LP
	TX0075370	National Oilwell Varco LP
	TX0075698	Harris County MUD No 8
	TX0076082	Country Terrace Water Co Inc
	TX0076945	Sequa Corp
	TX0077143	Georgia-Pacific Wood Products LLC
	TX0077585	Air Products LP
	TX0077887	Exxon Mobile Corp
	TX0078441	Galveston County WCID 12
	TX0079383	Aqua Utilities Inc
	TX0079570	International Airport Square Investments Ltd
	TX0079634	White Oak Owners Assn Inc
	TX0083836	AMC Facilities LP
	TX0083933	UA Holdings 1994-5 LP
	TX0084093	SC Pipe Services Inc Et Al
	TX0084115	Vopak Terminal Deer Park Inc
	TX0084581	Air Products LLC
	TX0084808	Metton America Inc
	TX0085618	City Of League City
	TX0085901	Bowie-Sims-Prange Inc
	TX0085961	Cotton Bayou Manor Mobile Home Park Inc
	TX0085979	Johann Haltermann Ltd
	TX0086002	Chemcentral Southwest LP
	TX0086100	Labarge Pipe & Steel Co
	TX0086118	Brazoria County MUD No 3
	TX0086380	Chambers County MUD No 1
	TX0086568	Pelican Island Storage Terminal Inc
	TX0087491	Varco LP
	TX0087599	Delta Tubular Processing LP
	TX0087971	Solvay Chemicals Inc
	TX0087998	Port Of Houston Authority
	TX0088111	City Of Houston-Houston Airport System
	TX0088455	V&M Star A Partnership With General & Limited Partners LP
	TX0089125	Exxon Mobil Corp
	TX0089192	Odfjell Terminals (Houston) LP
TX0089567	Geo Specialty Chemicals Inc	
TX0089761	Stan Trans Partners LP	
TX0089940	Weatherford Us LP	
TX0090506	Champs Water Co	

RETURNS	TX0091073	Sunoco Inc (R&M)
	TX0091227	The Lubrizol Corp
	TX0091235	LBC Houston LP
	TX0091855	Stolthaven Houston Inc
	TX0092568	Heritage Financial Group Inc
	TX0092614	H & R Reality Investments LLC
	TX0092711	Karbalai Rita And John Ghodratollah Karbalai
	TX0092991	Harris County MUD No 285
	TX0093475	Greens Parkway MUD
	TX0093548	QBN Corp
	TX0093572	5510 Acorn LLC
	TX0093823	Gulf Coast Utility Co Inc
	TX0094056	Robinson, J Wayne
	TX0094129	Oxbow Carbon & Minerals LLC
	TX0094226	Walker Water Works Inc
	TX0094463	CMH Parks Inc
	TX0094650	Utilities Investment Co Inc
	TX0094790	Aqua Utilities Inc
	TX0094803	Duco Inc
	TX0094935	Mirhaj Kobra
	TX0095451	Harris County MUD 285
	TX0095559	KMCO LP
	TX0095761	Hinojosa Rene
	TX0095770	K C Utilities Inc
	TX0095923	Bolivar Utility Services LLC
	TX0096172	City Of Houston
	TX0096679	Aqua Utilities Inc
	TX0096954	Houston East Resort Baytown Texas Inc
	TX0097071	Harris County MUD278
	TX0098604	Dome Petrochemical LC
	TX0099473	Port Of Houston Authority
	TX0099597	Chapman Sr, Pat Gene
	TX0100170	City Of Dayton
	TX0100919	Cogen Lyondell Inc
	TX0100935	Gulf Utility Service Inc
	TX0101109	BTEC Turbines LP
TX0101460	City Of Houston	
TX0101656	GE Packaged Power Inc	
TX0102024	Davis Bayou Service Co & Cypress Lakes Poa	
TX0102091	Monarch Utilities I LP	

RETURNS	TX0102296	Air Liquide Large Industries US LP
	TX0102326	Enterprise Products Operating LP
	TX0102385	City Of Arcola
	TX0103578	Powell Jackie Diane
	TX0103616	GSE Lining Technology Inc
	TX0103721	City Of Houston
	TX0103900	Equistar Chemicals LP
	TX0104051	Kinder Morgan Petcoke LP
	TX0104353	Ambar Lone Star Fluid Services LP Llp
	TX0104621	Gulf West Landfill TX LP
	TX0104965	Harris County MUD No 344
	TX0105406	Maxey Road WSC
	TX0106062	Sartomer Co Inc
	TX0106208	South Coast Terminals LP
	TX0106542	Kinder Morgan Petcoke LP
	TX0106721	Enterprise Products Operating LP
	TX0106861	Elg Metals Inc
	TX0106879	Federated Metals Corp
	TX0107301	Harris County
	TX0107956	Aramark Uniform & Career Apparel
	TX0108332	Conoco Phillips Pipe Line Co
	TX0108367	Sea Lion Technology Inc
	TX0108812	Enterprise Products Operating LP
	TX0109886	Meadowland Utility Corp
	TX0111350	Bayshore Industrial Inc
	TX0112259	Krebs, Stephen Paul
	TX0112704	Chusei USA Inc
	TX0112861	Hillman Shrimp & Oyster Co
	TX0113450	Ethyl Corp
	TX0114821	City Of La Marque
	TX0116581	City Of Pearland
	TX0116904	WLSK-Pasadena LLC
	TX0117234	Walker Water Works Inc
	TX0117447	Forestaire Estates
	TX0117528	City Of Pasadena
	TX0117552	Mirage Stop Inc
TX0117692	Hartman, James William	
TX0117757	Duratherm Inc	
TX0117897	Quarters LLC	
TX0117927	Ricetec Inc	

RETURNS	TX0118214	Chevron USA Inc
	TX0118222	GE Mobile Water Inc
	TX0118397	City Of Manvel
	TX0118427	Chemicals Incorporated
	TX0118575	Gulf Reduction Corp
	TX0118729	Lawson li, Donald Lee
	TX0118931	Christian Tabernacle Of Houston Inc
	TX0119041	Walker Water Works Inc
	TX0119059	Kinder Morgan Petcoke LP
	TX0119067	Aqua Development Inc
	TX0119075	Cooper, Jerry Lynn
	TX0119326	McCarty Road Landfill TX LP
	TX0119334	South Coast Terminals LP
	TX0119458	Waste Management Of Texas Inc
	TX0119482	Halliburton Energy Services Inc
	TX0119571	Aqua Utilities Inc
	TX0119792	Equistar Chemicals LP
	TX0122823	Manvel Utilities LP
	TX0123633	Brazoria County MUD 21
	TX0123978	Kinder Morgan Petcoke LP
	TX0123994	Sp Utility Co Inc
	TX0124001	Brazoria Co MUD No 29
	TX0124087	Texas Parks And Wildlife Dept
	TX0124303	Deer Park Energy LP And Calpine Operating Services Co Inc
	TX0124761	Crvc Via Bayou LLC
	TX0125326	Holy Trinity Episcopal School Of Greater Houston
	TX0125369	Regeant Chemical And Research Inc
	TX0125571	Western Oilfields Supply Co
	TX0125644	Dixie Chemical Company Inc
	TX0125661	Harris County MUD 400
	TX0125776	Bolivar Utilities Services LLC
	TX0125920	Marmac LLC
	TX0126187	Lake Municipal Utility District
	TX0126292	Delta Tubular International LP
	TX0126373	Dr James Donald Smith Jr
	TX0126381	Jas M Properties No 3 LLC
TX0126471	Siemens Water Technologies Corp	
TX0126543	City Of Baytown	
TX0126756	Harris County MUD No 412	
TX0126781	Auc Group LP	

RETURNS	TX0126977	Galveston County MUD 1
	TX0127124	Harris Co MUD No 278
	TX0127329	Precision Tube Technology LP
	TX0127728	Lake MUD
	TX0127981	Marhaba Partners LP
	TX0128015	LCY Elastomers LP
	TX0128261	Woodmere Development Co Ltd
	TX0128325	Chambers County Improvement District No 1
	TX0128783	Broyles, John
	TX0129496	Bollinger Texas City LP
	TX0129747	Ipsco Koppel Tubulars Corp
	TX0129917	Vam USA
	TX0130036	National Oilwell Varco LP

*NPDES = National Pollutant Discharge Elimination System

Appendix B. Record of coastal hydrology versions developed by the TWDB Bays & Estuaries Program for the Trinity-San Jacinto Estuary.

Estuary	Version	Date Range	Gaged Flows	Ungaged Flows	Diversions	Return Flows	Creation Date
Trinity-San Jacinto	TWDB201001	1941-2008	1941-2008	1941-2008	1941-2005 TDWR 1941-1976 TCEQ 1977-2005	1941-2007 TDWR 1941-1976 TCEQ 1977-2007 TWDB 1977-2005 (Agricultural)	01/2010
	TWDB201002	Dataset does not exist.					
	TWDB201003	Dataset does not exist.					
	TWDB201004	1941-2009	1941-2009 USGS provisional 12/09	1941-2009 Precipitation data provisional for 12/09	1941-2009 TDWR 1941-1976 TCEQ 1977-2009	1941-2009 TDWR 1941-1976 TCEQ 1977-2009 TWDB 1977-2007 (Agricultural)	09/2010
	TWDB201101	1941 - 2010	1941 – 2010 USGS provisional after 9/10	1941 – 2010 Precipitation data provisional after 8/10	1941– 2009 TCEQ 1977 - 2009	1941 – 2009 TCEQ 1977 – 2009 TWDB 1977 – 2007 (Agricultural)	08/2011

Appendix C. Annual hydrology for the Trinity-San Jacinto Estuary as calculated for version #TWDB201101. Included are estimates of gaged and ungaged (modeled) inflows, diversions and return flows, combined surface inflow to the estuary, as well as evaporation and direct precipitation on the estuary and the total freshwater balance of the estuary. All values are in units of acre-feet.

Year	Gaged	Ungaged (Modeled)	Diversion	Return	Combined Surface Inflow*	Evaporation	Precipitation	Freshwater Balance**
1941	14,476,600	4,899,000	120,000	122,000	19,377,600	1,121,000	2,349,356	20,605,956
1942	11,005,600	2,574,000	145,000	136,000	13,570,600	1,268,000	1,715,592	14,018,192
1943	5,153,210	2,651,000	192,000	152,000	7,764,210	1,267,000	1,756,858	8,254,068
1944	10,633,030	3,860,000	191,000	151,000	14,453,030	1,267,000	1,818,763	15,004,793
1945	15,565,400	4,438,000	184,000	154,000	19,973,400	1,267,000	2,137,119	20,843,519
1946	14,487,350	6,238,000	183,000	160,000	20,702,350	1,238,000	2,885,848	22,350,198
1947	6,872,810	1,561,000	182,000	162,000	8,413,810	1,266,000	1,226,265	8,374,075
1948	4,413,680	1,109,000	240,000	171,000	5,453,680	1,266,000	996,340	5,184,020
1949	8,129,670	4,807,000	259,000	192,000	12,869,670	1,239,000	2,187,233	13,817,903
1950	9,063,520	1,874,000	220,000	187,000	10,904,520	1,414,000	1,267,533	10,758,053
1951	1,777,170	713,000	277,000	206,000	2,419,170	1,385,000	1,176,153	2,210,323
1952	3,157,810	2,019,000	249,000	205,000	5,132,810	1,386,000	1,435,554	5,182,364
1953	5,466,320	2,179,000	230,000	193,000	7,608,320	1,463,000	1,585,891	7,731,211
1954	1,691,350	356,000	279,000	279,000	2,047,350	1,592,000	798,840	1,254,190
1955	2,239,430	1,768,000	214,000	321,000	4,114,430	1,532,000	1,577,046	4,159,476
1956	1,053,280	599,000	106,000	325,000	1,871,280	1,592,000	1,037,608	1,316,888
1957	13,759,230	3,772,000	143,000	321,000	17,709,230	1,443,000	1,680,219	17,946,449
1958	7,004,000	2,312,000	183,000	351,000	9,484,000	1,414,000	1,518,093	9,588,093
1959	6,910,380	3,993,000	191,000	349,000	11,061,380	1,652,000	1,748,019	11,157,399
1960	8,491,920	2,767,000	215,000	374,000	11,417,920	1,534,000	1,518,093	11,402,013
1961	9,596,390	4,070,000	235,000	389,000	13,820,390	1,503,000	1,868,874	14,186,264
1962	4,255,100	939,000	271,000	421,000	5,344,100	1,532,000	1,176,153	4,988,253
1963	2,003,210	677,000	266,000	446,000	2,860,210	1,208,000	869,588	2,521,798
1964	2,937,980	1,395,000	219,000	448,000	4,561,980	1,238,000	1,202,682	4,526,662
1965	5,357,240	1,038,000	238,000	473,000	6,630,240	1,533,000	1,120,147	6,217,387
1966	7,627,190	3,656,000	204,000	514,000	11,593,190	1,031,000	1,930,778	12,492,968
1967	2,330,770	801,000	265,000	543,000	3,409,770	1,295,000	1,099,511	3,214,281
1968	10,370,930	3,295,000	244,000	551,000	13,972,930	1,270,000	1,630,108	14,333,038
1969	8,878,470	2,187,000	252,000	562,000	11,375,470	1,327,000	1,579,994	11,628,464
1970	4,095,940	2,957,000	266,000	575,000	7,361,940	1,358,000	1,733,279	7,737,219
1971	2,697,888	1,109,000	260,000	615,000	4,161,888	1,574,000	1,288,168	3,876,056
1972	4,023,806	2,469,000	220,000	625,000	6,897,806	1,445,000	1,397,233	6,850,039
1973	15,422,740	5,684,000	211,000	559,000	21,454,740	1,408,000	2,231,448	22,278,188
1974	10,357,101	2,822,000	251,000	632,000	13,560,101	1,502,000	1,591,786	13,649,887
1975	8,993,864	2,182,000	221,000	610,000	11,564,864	1,418,000	1,871,823	12,018,687
1976	4,907,017	1,263,000	205,000	695,000	6,660,017	1,485,000	1,385,442	6,560,459

Year	Gaged	Ungaged (Modeled)	Diversion	Return	Combined Surface Inflow*	Evaporation	Precipitation	Freshwater Balance**
1977	6,126,925	2,091,742	268,035	505,975	8,456,607	1,547,943	1,224,396	8,133,060
1978	3,034,318	1,601,945	299,375	581,619	4,918,507	1,517,345	960,109	4,361,271
1979	12,696,355	6,407,018	379,531	636,229	19,360,071	1,508,969	2,025,941	19,877,043
1980	5,251,834	2,400,643	364,302	595,919	7,884,094	1,623,845	1,180,490	7,440,739
1981	7,838,694	3,929,039	378,946	604,331	11,993,118	1,578,534	1,626,840	12,041,424
1982	8,666,392	2,126,540	367,376	561,857	10,987,413	1,585,170	1,168,877	10,571,120
1983	8,245,771	5,070,917	281,131	557,854	13,593,411	1,542,164	1,731,680	13,782,927
1984	5,714,613	1,692,507	347,826	560,863	7,620,157	1,671,479	1,065,469	7,014,147
1985	8,856,836	3,543,992	334,756	551,200	12,617,272	1,588,343	1,426,017	12,454,946
1986	9,935,074	3,187,873	386,518	553,223	13,289,652	1,566,118	1,327,494	13,051,028
1987	6,918,509	3,068,318	445,502	548,167	10,089,492	1,684,177	1,287,309	9,692,624
1988	2,672,452	1,088,027	424,544	502,448	3,838,383	1,519,940	1,047,656	3,366,099
1989	9,526,245	3,238,426	440,002	505,515	12,830,184	1,375,617	1,408,050	12,862,617
1990	12,185,755	2,046,846	444,808	501,060	14,288,853	1,414,002	1,284,824	14,159,675
1991	12,272,352	5,395,070	577,096	518,745	17,609,071	1,502,332	1,931,901	18,038,640
1992	16,519,941	4,485,031	621,416	485,230	20,868,786	1,392,356	1,600,708	21,077,138
1993	12,136,257	4,016,545	582,145	386,039	15,956,696	1,660,790	1,481,391	15,777,297
1994	12,458,175	3,687,951	568,981	460,333	16,037,478	1,498,868	1,277,429	15,816,039
1995	10,945,745	4,138,062	646,444	482,742	14,920,105	1,407,081	1,715,593	15,228,617
1996	2,691,689	2,166,434	664,445	488,846	4,682,524	1,459,612	1,223,787	4,446,699
1997	11,847,420	4,895,105	689,092	454,499	16,507,932	1,504,640	1,880,418	16,883,710
1998	13,616,744	5,163,895	729,513	477,590	18,528,716	1,651,077	2,025,985	18,903,624
1999	5,360,132	1,715,787	677,106	434,677	6,833,490	1,318,246	1,110,167	6,625,411
2000	4,805,713	2,084,803	186,642	470,162	7,174,036	1,394,372	1,274,400	7,054,064
2001	14,725,868	6,778,958	93,358	584,014	21,995,482	1,374,697	2,270,695	22,891,480
2002	10,285,764	5,246,823	39,000	625,340	16,118,927	1,366,548	1,988,636	16,741,015
2003	7,269,265	3,431,071	49,695	632,751	11,283,392	1,059,068	1,635,784	11,860,108
2004	12,318,406	4,619,839	70,073	696,800	17,564,972	1,096,492	1,778,451	18,246,931
2005	6,048,470	1,971,228	156,516	576,359	8,439,541	1,304,239	1,175,848	8,311,150
2006	4,050,891	4,567,301	90,922	578,936	9,106,206	1,333,950	1,793,406	9,565,662
2007	12,651,480	4,756,622	84,927	632,167	17,955,342	1,247,937	1,740,175	18,447,580
2008	6,501,943	3,716,184	70,681	525,647	10,673,093	1,324,601	1,488,283	10,836,775
2009	8,191,705	2,994,886	67,486	541,312	11,660,417	1,271,979	1,460,625	11,849,063
2010	7,606,591	2,419,681	n/a	n/a	10,026,272	1,290,198	1,258,683	9,994,757

*Combined Surface Inflow = Gage + Model - Diversion + Return

**Freshwater Balance = Surface Inflow – Evaporation + Precipitation

Appendix D. Summary statistics for annual freshwater inflows (in acre-feet) over the 1941 - 2010 period for the Trinity-San Jacinto Estuary based on hydrology version #TWDB201101.

	Gaged	Ungaged (Modeled)	Diversion	Return	Combined Surface Inflow	Evaporation	Precipitation	Freshwater Balance
MIN	1,053,280	356,000	39,000	122,000	1,871,280	1,031,000	798,840	1,254,190
5%ile	2,109,509	752,600	70,316	152,800	3,107,512	1,160,150	1,014,911	2,833,415
10%ile	2,689,765	1,083,024	92,871	169,200	4,157,142	1,238,900	1,096,107	4,131,134
25%ile	4,831,039	1,898,307	186,642	349,000	6,966,864	1,291,399	1,224,863	6,891,066
MEDIAN	7,732,942	2,794,500	244,000	501,060	11,172,386	1,414,000	1,503,188	11,279,706
MEAN	7,931,167	3,011,116	284,916	449,093	11,104,116	1,413,082	1,532,442	11,223,476
75%ile	10,867,566	4,056,636	364,302	562,000	14,411,986	1,532,000	1,754,648	14,836,854
90%ile	13,630,993	5,080,215	578,106	625,068	18,611,852	1,592,000	2,025,945	19,000,966
95%ile	14,618,535	5,553,982	657,245	632,517	20,374,323	1,651,585	2,211,551	20,972,009
MAX	16,519,941	6,778,958	729,513	696,800	21,995,482	1,684,177	2,885,848	22,891,480
TOTAL All Years	555,181,720	210,778,109	19,659,190	30,987,449	777,288,088	98,915,729	107,270,954	785,643,313